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Managing Distributed Context Models Requires Adaptivity too

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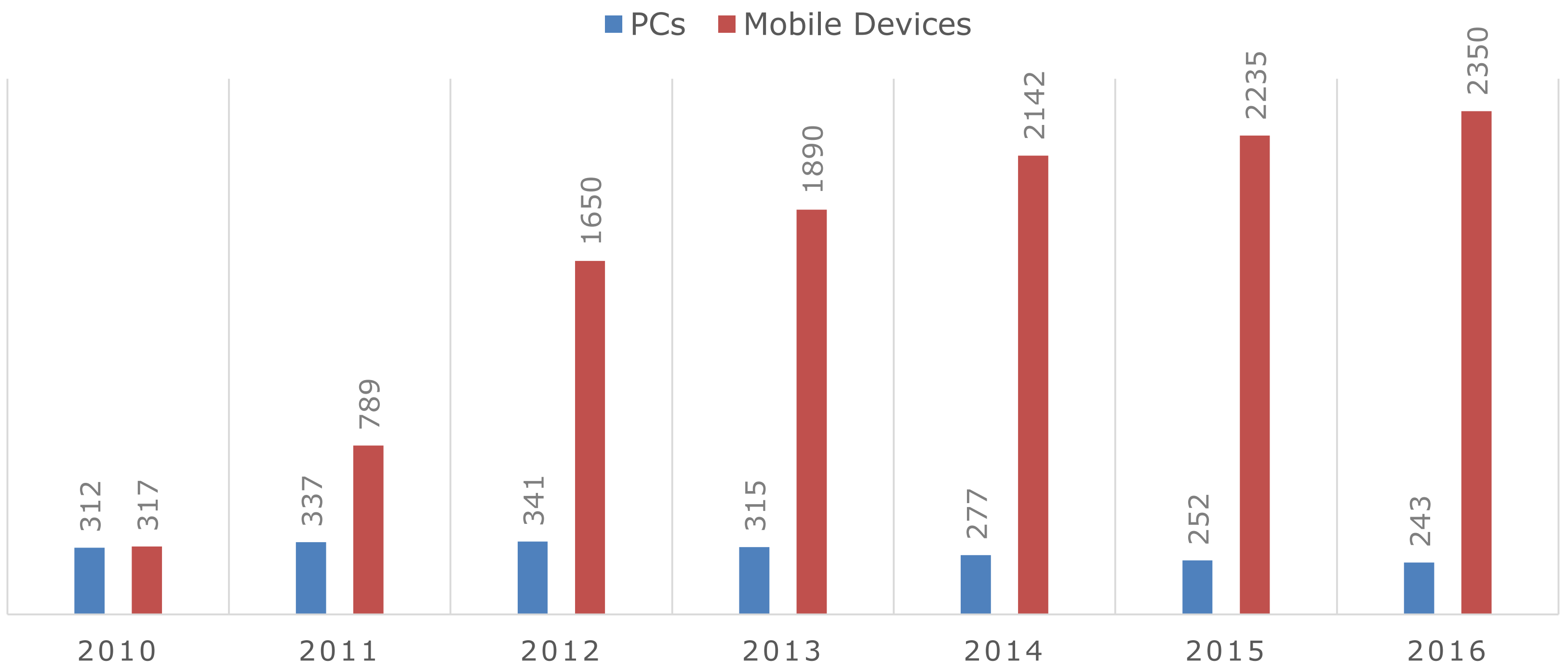
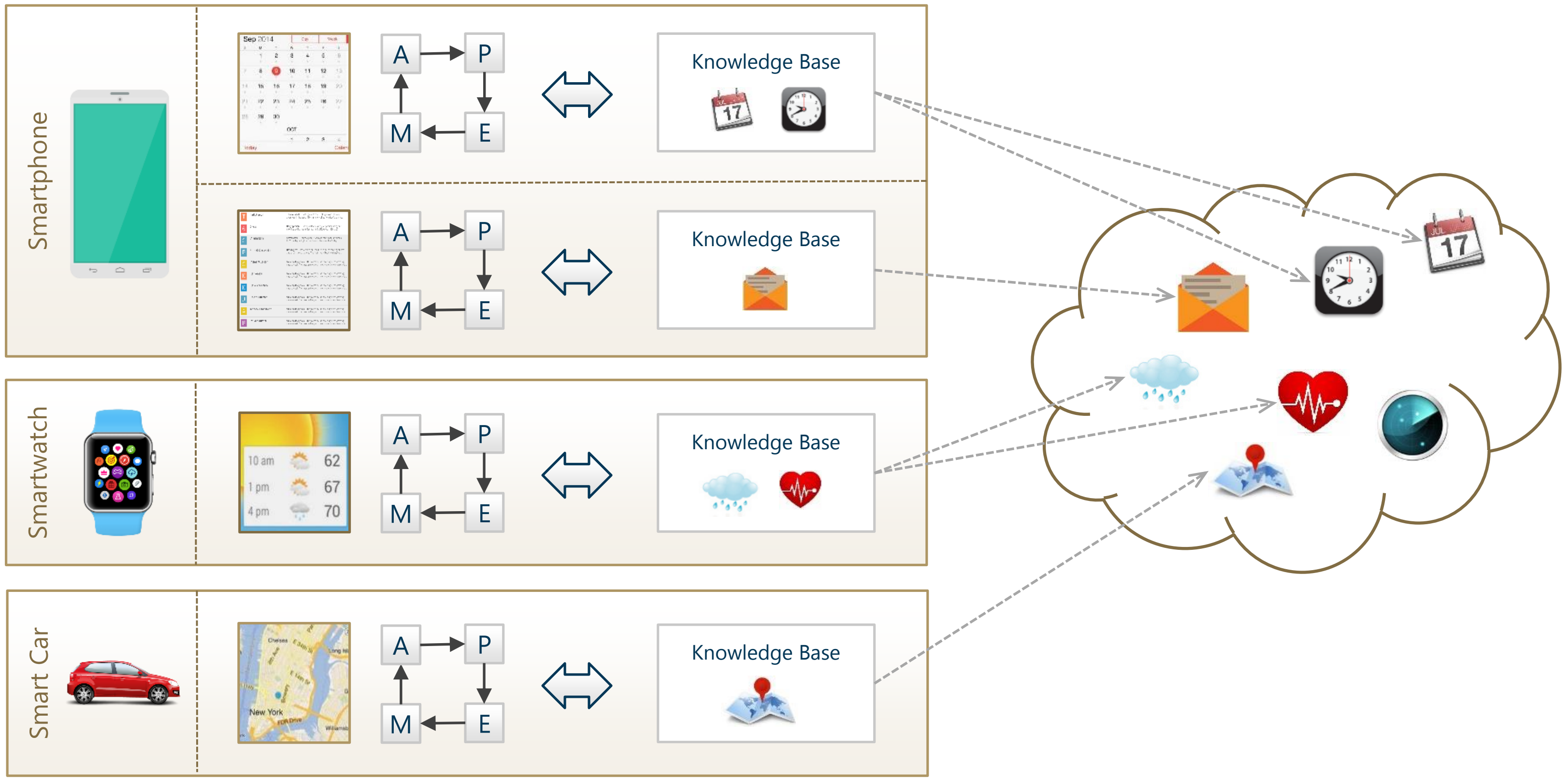
Trend Towards Mobile Computing Devices



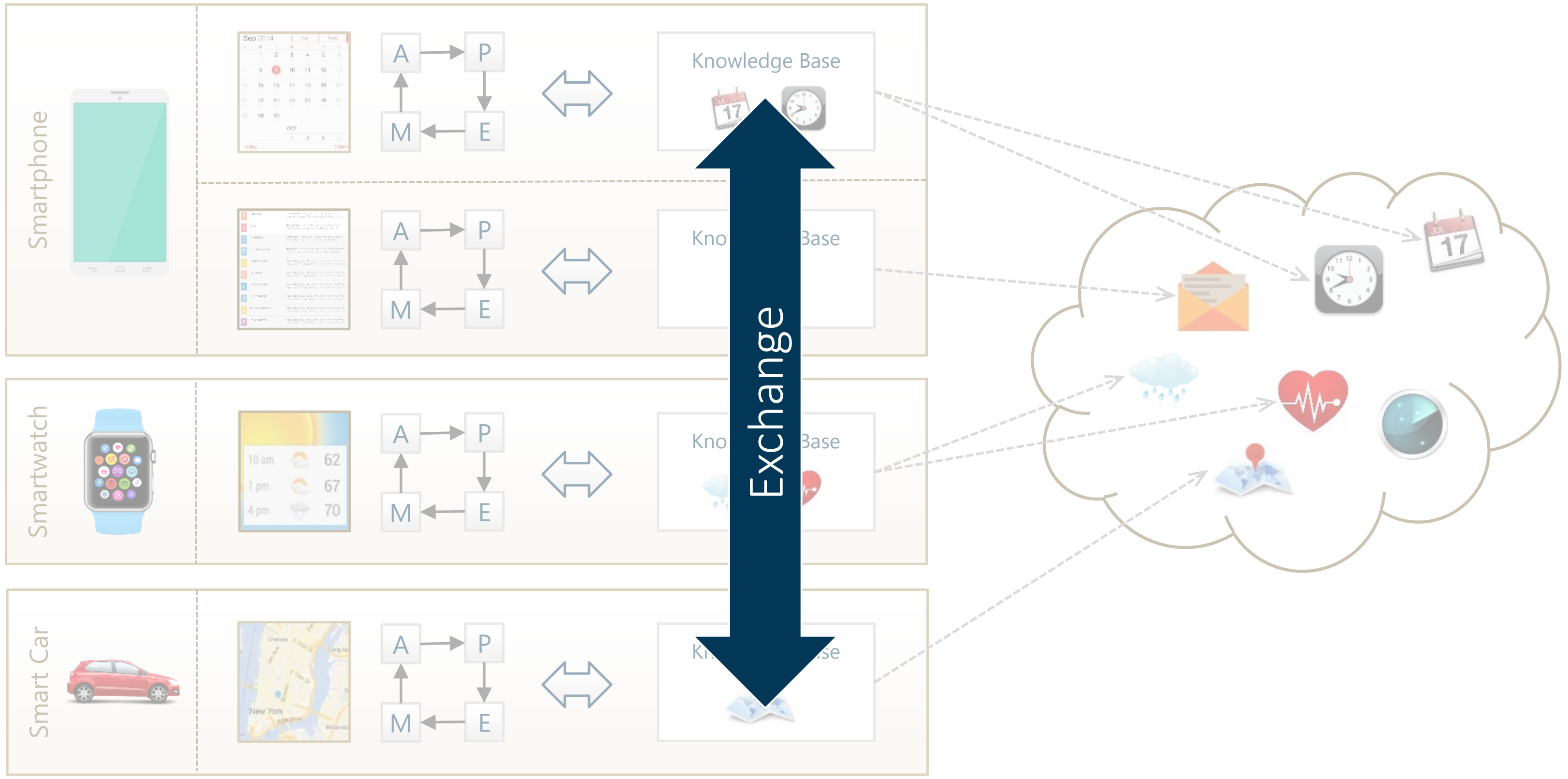
1000 Sales of devices (Source Gartner)

Mobility = Changing Contexts = Changing Requirements

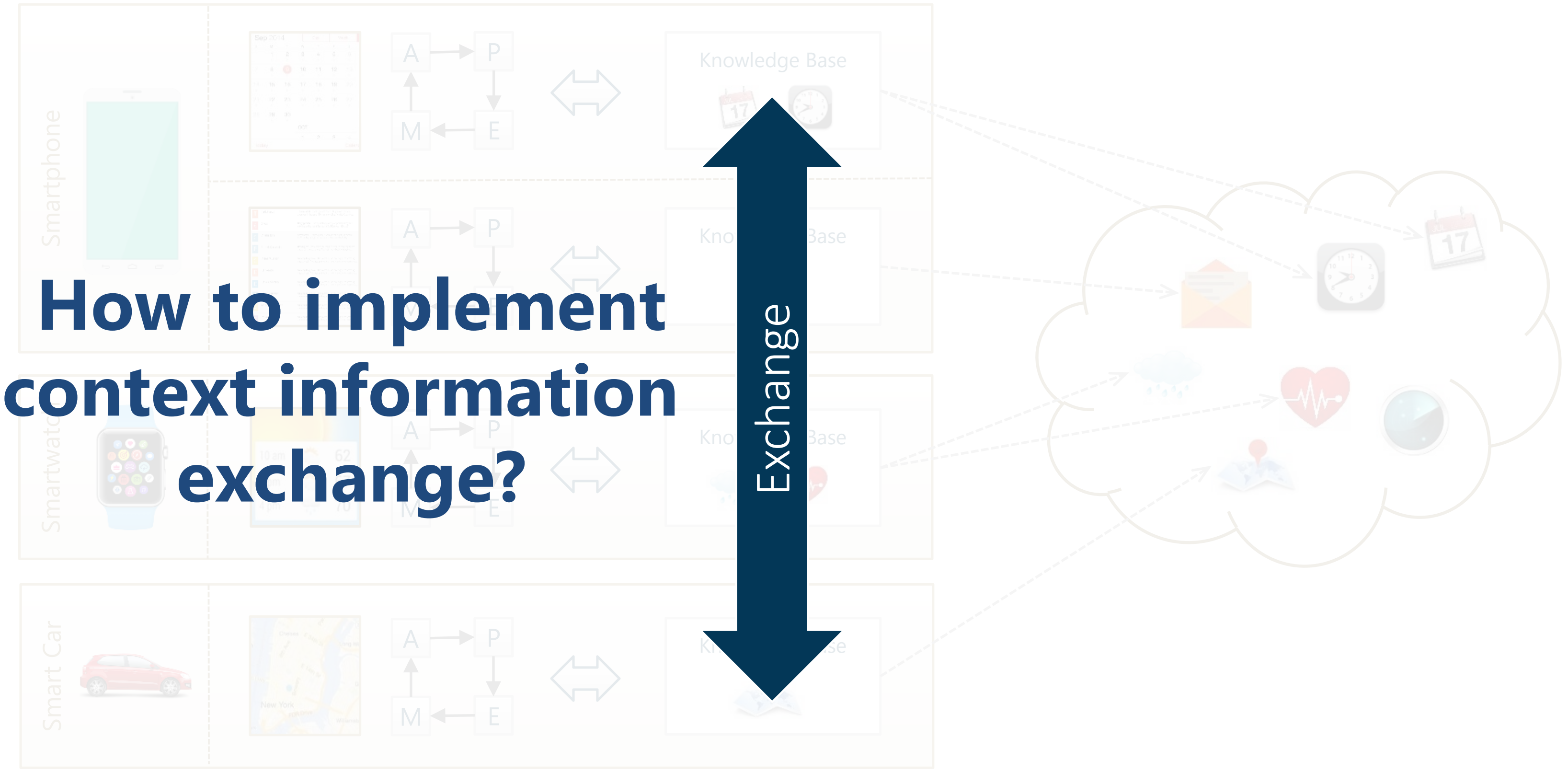
Individual apps may have different context information



Individual apps may have different context information



Individual apps may have different context information



How to implement context information exchange?

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Managing Distributed Context Models Requires Adaptivity too

VARIATION DIMENSIONS

Approach

Literature Study

- Investigation of 16 publications of technologies with the ability to exchange context information
- Result: Different strategies are used for different aspects
    1. **What** context information is accessible
    2. **When** context information should be exchanged
    3. **Who** initiates the exchange of context information
    4. **How** should context information be managed
    5. **Where** should context information be managed
- Concrete strategy depends on concrete requirements (may change at runtime)

  → *e.g., data traffic, expressiveness, size of the models, performance, ability to handle privacy constraints*

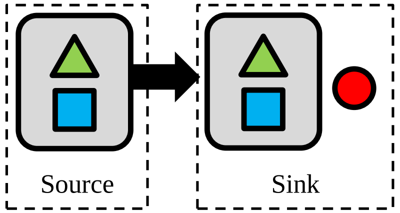
  → Context model management must itself be adaptive

  → Meta-Adaptation required

1) What context information is accessible

1.A Complete

- Most common solution
- Sink as full access to the context model of the source

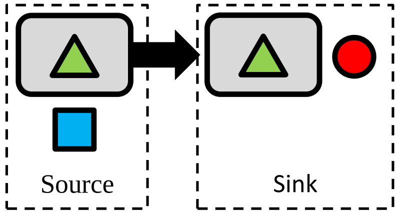


- Sink can decide which information is relevant
- Privacy issues cannot be addressed
- Potentially a large amount of data traffic

1) What context information is accessible

1.B Partial

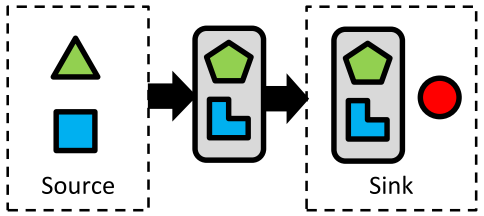
- Not all context information *should be accessible by* or *are relevant for the sink*
- Access to information might restricted
  → Privacy issues can be addressed
- Sink has the option to exclude irrelevant information
  → Data traffic might be reduced
- Higher complexity



1) What context information is accessible

1.C View-Based

- Source provides views on the context model
- Explicit handling of privacy issues
- Reduction of data traffic due to potential abstraction
- Views can be defined by the source or sink

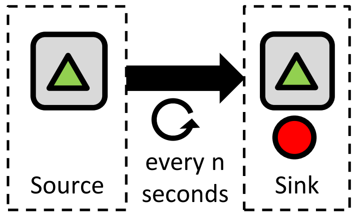


2) When context information should be exchanged

2.A Periodically

- Information is pulled or pushed in certain time intervals
- Update frequency defined statically or dynamically

- Easy to implement
- Potentially unnecessary data traffic due to transfer of unchanged information
- Subsampling must be prevented

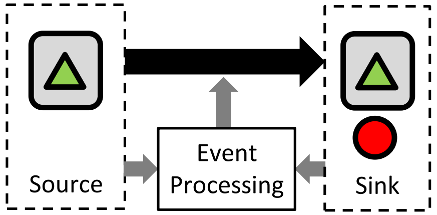


2) When context information should be exchanged

2.B Event-Based

- Source and/or sink can produce events
- Event processing leads to context information exchange

  e.g., a certain value changed a certain amount



- Reduce data traffic
- Prevent subsampling
- Introduction of further complexity

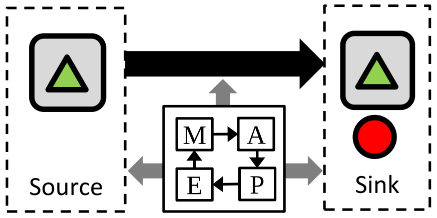
2) When context information should be exchanged

2.C Context-Based

- Context-dependent exchange
- Feedback loop decides based on context information

  e.g., two devices are very close

- Higher complexity
- Higher flexibility (auto-tune data-traffic etc.)



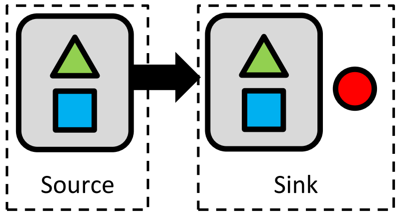
3) Who initiates the exchange of context information

3.A Source

- Source proactively distributes context information

- Source has full control what data is distributed
  → improves privacy issue handling
  → may reduce data traffic (e.g., only pushed when value changed)

- Sink may not be able to specify what information is relevant
  → may increase necessary data traffic



3) Who initiates the exchange of context information

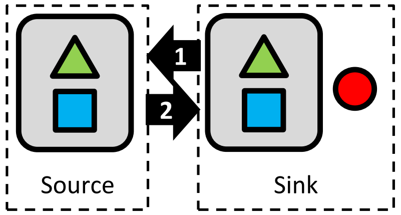
3.B Sink

- Sink pulls context information
- Source sends information as response

- Source has full control what data is distributed

  → improves privacy issue handling

  → may reduce data traffic (e.g., only pushed when value changed)
- Sink may not be able to specify what information is relevant

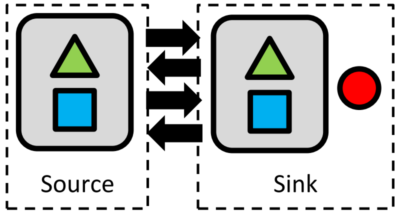


3) Who initiates the exchange of context information

3.C Negotiation

- Combination of source- and sink-based initiation in a black-board architecture
- Sinks can access the context model via a query interface
- Source might grant or deny access and might offer views
- Sinks may be able to register for certain events and get notified

- Higher complexity
- Higher flexibility



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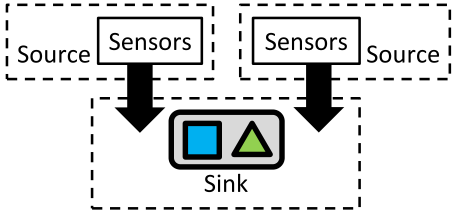
4) Where should context information be managed

4.A Centralized

- Central server manages one context model for multiple clients
- Every updated value is sent to the sink



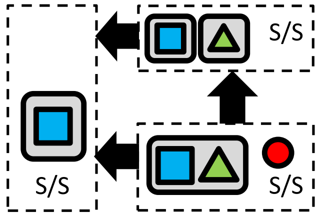
- Reduction of the number of required connections
- Reduction of data traffic
- For devices with limited resources (e.g., main memory) this might be beneficial

- Single point of failure
- Potentially large single model
- Handling privacy issues gets complicated

4) Where should context information be managed

4.B Decentralized

- Applications manage their own context model and are able to exchange context information with other applications



- Handling privacy issues possible
- Decrease the size of the individual models (compared to the centralized approach)

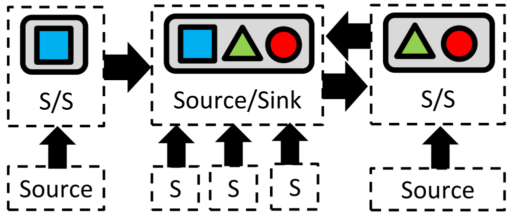
- Higher number of required connections
- Potentially decreased data traffic

4) Where should context information be managed

4.C Hybrid

- Combination of centralized and decentralized approaches
- Multiple central sinks that are connected in a peer-to-peer network
- Applications can be grouped in a centralized style while the sinks can exchange context information
- Concrete architecture might be defined statically or organized dynamically

- Possible to dynamically combine the benefits of both approaches

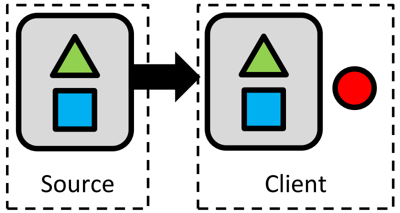


5) How should context information be managed

5.A Copy

- Sink copies the received information into the own context model
- Most common strategy

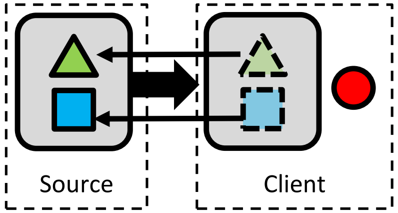
- Easy to implement
- Suitable when number of reads exceed to the number of writes



5) How should context information be managed

5.B Proxy

- Sink stores a reference to the actual (remotely available) information
- Every read gets transformed into a remote call



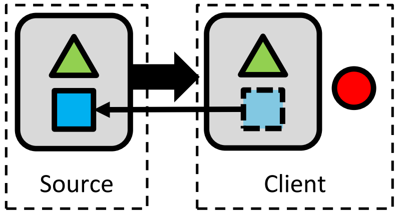
- Size of the stored data is decreased
- Decrease data traffic when the number writes exceed to the number of reads

- Evaluation performance is decreased

5) How should context information be managed

5.C Hybrid

- Some information is copied other managed by proxies
- Dynamic decision based on read/write characteristics



- Optimization of data traffic
- Optimization of the size of the managed models

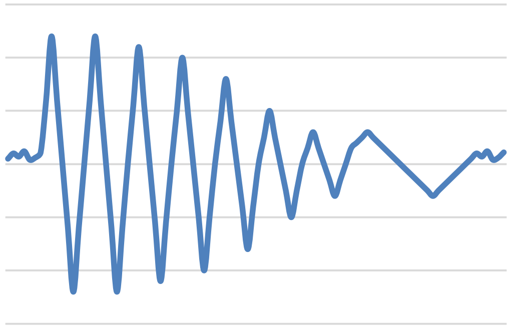
- Higher complexity (additional monitoring components required)

GOAL: Show feasability

- Only a small first example

- **Domain**: Blended Interactive Spaces (Multi-Device Interaction)
- **Use Case**: *Bump-to-Give Interaction Pattern*
  When two devices are bumped together, content (e.g., an image) is transferred from one device to the other

- **Recognition**: A special function on accelerometer data
  → Both devices must show this pattern at the same point of time

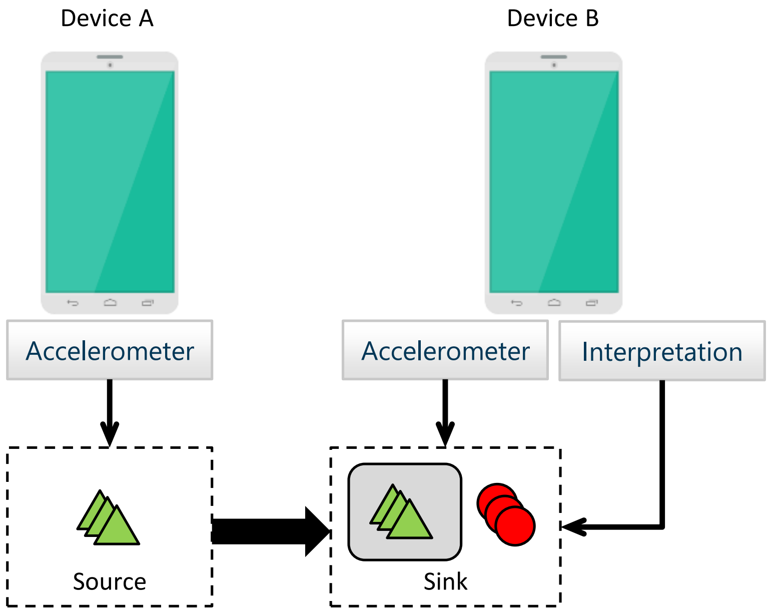


Copy-based

- Interpretation of the data of both devices on *Device B*
- Copying the accelerometer data from *Device A* to *Device B*

- Very easy to implement
  → Synchronization etc. can be done on one device

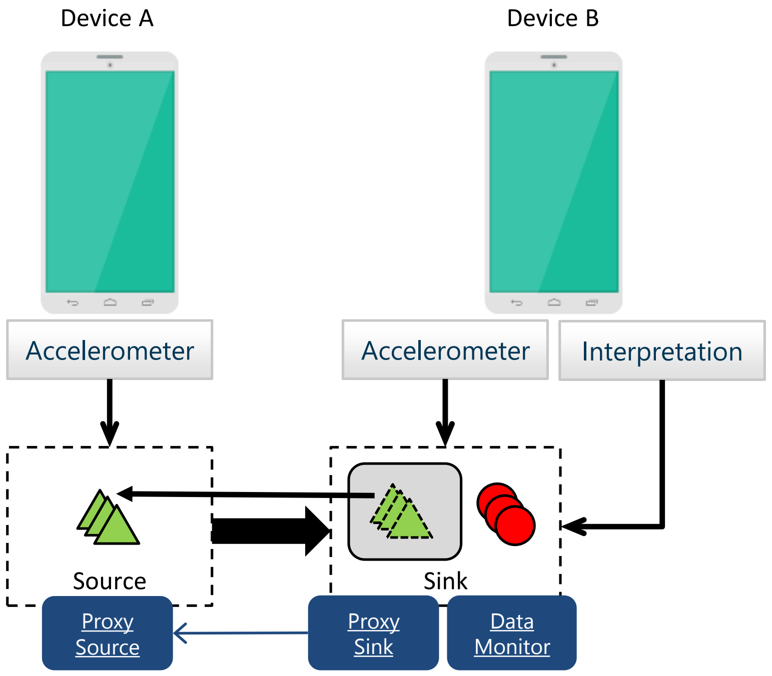
- **Data Traffic: 20kB/s**
- Data of *Device A* is only read when the interpretation of the data of *Device B* detects a bump



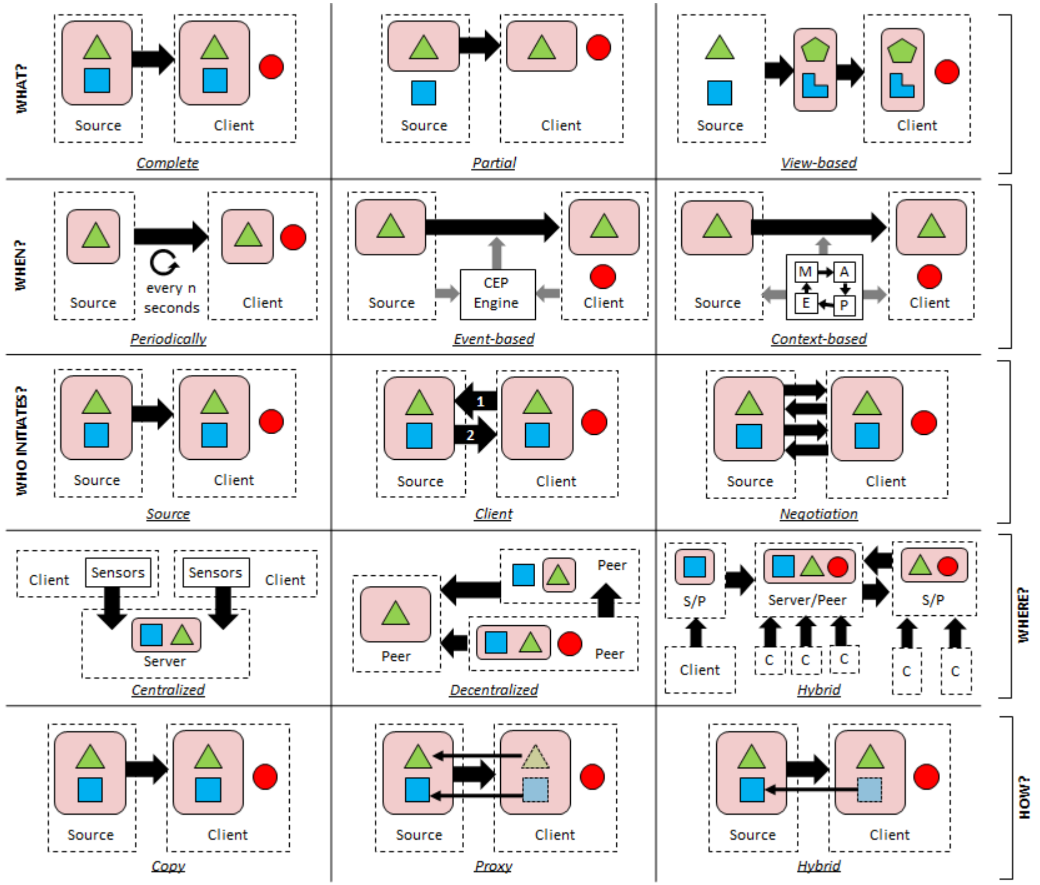
Proxy-Based

- DataMonitor roles monitors read/write access of context information
- When read/write actions exceeds a ration of 1:2, values are no more copied but a reference stored
  → Actual values are no longer transferred
  → When information is read, a remote call is generated

- **Data Traffic: Almost 0kB/s**
- Interpretation takes a little bit longer (337ms more)
  → hardly recognizable



Thank You!


WHAT?
Source
Client
Complete
Source
Client
Partial
Source
Client
View-based
WHEN?
Source
every n seconds
Client
Periodically
Source
CEP Engine
Client
Event-based
Source
M
A
E
P
Client
Context-based
WHO INITIATES?
Source
Client
Source
1
2
Source
Client
Client
Source
Client
Negotiation
Client
Sensors
Sensors
Client
Server
Centralized
Peer
Peer
Peer
Decentralized
S/P
Server/Peer
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C
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Hybrid
WHERE?
Source
Client
Copy
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Client
Proxy
Source
Client
Hybrid
HOW?